J Raptor Res. 37(3):188–197
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RED-SHOULDERED HAWK (*BUTEO LINEATUS*) ABUNDANCE AND HABITAT IN A RECLAIMED MINE LANDSCAPE

MELISSA J. BALCERZAK AND PETRA BOHALL WOOD[1]
West Virginia Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, and Division of Forestry, West Virginia University, P.O. Box 6125, Morgantown, WV 26506-6125 U.S.A.

ABSTRACT.—Fragmentation of the landscape by large-scale mining may affect Red-shouldered Hawk (*Buteo lineatus*) populations by reducing the amount of forested habitat available in a landscape and by creating fragmented forest patches surrounded by reclaimed mine lands. We examined habitat characteristics and relative abundance of Red-shouldered Hawks in reclaimed mine landscapes within four treatments: early-successional grassland habitat, mid-successional shrub/pole habitat, late-successional fragmented forest habitat, and late-successional intact forest habitat. We quantified microhabitat characteristics within an 11.3-m-radius plot centered on 156 vegetation plots throughout the four treatments. We surveyed 48 stations on and adjacent to three mines for Red-shouldered Hawks using standardized broadcast call techniques during February 2000–January 2001 and measured landscape characteristics within 1000-m buffer zones centered on each station from digitized aerial photographs. Mean abundance of Red-shouldered Hawks was significantly higher in the intact forest ($\bar{x}$ = 0.07 detections/point, SE = 0.03) than the grassland ($\bar{x}$ = 0.01, SE = 0.01) treatment, but did not differ from the fragmented forest ($\bar{x}$ = 0.03, SE = 0.01) or shrub/pole ($\bar{x}$ = 0.03, SE = 0.01) treatments. Most microhabitat characteristics in both fragmented and intact forest differed from shrub/pole and grasslands. Amount of wetland was the most important characteristic determining presence of Red-shouldered Hawks in a forest-dominated landscape. More wetlands in the landscape may provide abundant amphibians and reptiles, which are important in the diet of Red-shouldered Hawks.

KEY WORDS: Buteo lineatus; *Red-shouldered Hawk; habitat use; landscape; microhabitat; mining.*

ABUNDANCIA Y HABITAT DEL GAVILAN DE HOMBROS ROJOS (*BUTEO LINEATUS*) EN UN PAISAJE DE MINERIA RESTAURADO

RESUMEN.—La fragmentación del paisaje por la minería a gran escala puede afectar a las poblaciones del gavilán de hombros rojos (*Buteo lineatus*) mediante la reduccion de la cantidad de hábitat de bosque disponible en un paisaje, creando parches de bosque fragmentado rodeados por tierras de minería restauradas. Examinamos las características del hábitat y la abundancia relativa del halcón de hombros rojos en paisajes de minería restaurados, con cuatro tratamientos: hábitat de pradera de sucesión temprana, hábitat de arbustos de sucesión media, hábitat de bosque fragmentado de sucesión tardío, y hábitat de bosque intacto de sucesión tardío. Cuantificamos las características micro hábitat en una parcela de 11.3 m de radio, en 156 cuadrantes de vegetación con los cuatro tratamientos. Inspeccionamos 48 estaciones para el gavilán de hombros rojos dentro y en sitios adyacentes a tres minas, utilizando técnicas de emisión de vocalizaciones estandardizadas durante febrero del 2000–enero 2001. Se midieron las características del paisaje dentro de zonas de amortiguación de 1000 m centradas en cada estación determinada a partir de fotografías aéreas digitalizadas. La abundancia media del gavilán de hombros rojos fue apreciablemente más alta en el bosque intacto ($\bar{x}$ = 0.07 detección/ punto, SE = 0.03) que en el tratamiento de la pradera ($\bar{x}$ = 0.01, SE = 0.01), pero no difirió de los tratamientos de bosque fragmentados ($\bar{x}$ = 0.03, SE = 0.01) ni del de arbustos ($\bar{x}$ = 0.03, SE = 0.01). La mayoría de las características de los micro hábitat en bosques fragmentados e intactos difirieron de los de arbustos y praderas. La existencia de humedales fue la característica más importante para determinar la presencia de gavilanes de hombros rojos en un paisaje dominado por bosque. El aumento de humedales en el paisaje podría proporcionar mayor abundancia de anfibios y reptiles, los cuales son muy importantes en la dieta del gavilán de hombros rojos.

[Traducción de César Márquez]

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[1] Corresponding author's e-mail address: pbwood@wvu.edu

The eastern subspecies of the Red-shouldered Hawk (*Buteo lineatus lineatus*) is considered primarily a forest species that breeds in large tracts of contiguous, mature forest (Hall 1983, Buckelew and Hall 1994, Crocoll 1994), although some populations thrive in suburban landscapes (Dykstra et al. 2001). Although quantitative data are lacking, trends suggest a long-term decline in the numbers of Red-shouldered Hawks in several northern states, including New Jersey, Illinois, Iowa, New York, Michigan, and Wisconsin (Peterson and Crocoll 1992, Crocoll 1994). A number of states attributed the decline primarily to reduction of closed canopy forest due to logging, agriculture, urban development, and drainage of wooded wetlands; and secondarily to competition with Red-tailed Hawks (*Buteo jamaicensis*) (Peterson and Crocoll 1992). Red-shouldered Hawk populations in West Virginia appear stable (Sauer et al. 2001) with confirmed breeding in 34 out of 455 Breeding Bird Survey blocks and probable or possible breeding in 123 blocks (Buckelew and Hall 1994).

Nest-site selection studies of Red-shouldered Hawks have concluded that they select large, mature stands of deciduous trees that have a well developed canopy layer and reduced understory e.g., (Portnoy and Dodge 1979, Titus and Mosher 1981, Bednarz and Dinsmore 1982, Morris and Lemon 1983, Bloom et al. 1993). Nest sites also have been associated with floodplain forest near areas of open water (Bent 1937, Titus and Mosher 1981, Bednarz and Dinsmore 1981, 1982, Moorman and Chapman 1996). Other studies have shown Red-shouldered Hawks to nest in upland, hardwood forests rather than floodplain forest, but still in close proximity to water (Crocoll and Parker 1989, Belleman 1998). Bednarz and Dinsmore (1982) found that Red-shouldered Hawks in Iowa used upland forest habitat immediately adjacent to floodplains, and they suggested that this adjacent upland forest may be used when floodplain forest is limited in area.

No previous studies have examined the effect of mountaintop mining on Red-shouldered Hawks, although the loss and fragmentation of forest and creation of edge by the mountaintop mining process may have negative effects on this species. Clearing of forests and creation of fragmented forest patches surrounded by reclaimed grassland may decrease the suitability of mountaintop mined areas and lead to lower abundance of forest raptor populations that occupy and breed in large blocks of intact forest. In a study on 12 reclaimed surface mines in northern West Virginia and southern Pennsylvania, Mindell (1978) noted that although American Kestrels (*Falco sparverius*) and Red-tailed Hawks were relatively common, other raptor species such as Red-shouldered Hawks were much less common. On reclaimed surface mines in northern West Virginia, Forren (1981) found no Red-shouldered Hawks using artificial perches and made no mention of their presence on the surface mine at any time. In these studies, reclaimed mines were approximately 0.7–40 ha in size, while mountaintop mines typically are much larger and encompass hundreds to thousands of hectares. Creation of edge also may increase competition between Red-shouldered Hawks and Red-tailed Hawks for nesting areas, because forest fragmentation and large open areas favor the latter species (Bednarz and Dinsmore 1982, Preston and Beane 1993, Moorman and Chapman 1996). To assess the impact of these relatively large-scale mountaintop mines on a forest raptor, we quantified relative abundance of Red-shouldered Hawks and examined landscape characteristics important to this species in southern West Virginia.

Study Area

We quantified Red-shouldered Hawk relative abundance and habitat characteristics at three mountaintop mines in the southern West Virginia counties of Boone, Logan, Kanawha, and Fayette. Reclaimed areas at each mine encompassed 2431 ha, 2180 ha, and 1819 ha. Study areas were divided into four treatments: intact forest, fragmented forest, young reclaimed mine (grassland), and older reclaimed mine (shrub/pole). The intact forest treatment included mature forest on ridgetops, midslopes, and along first and second order streams and was located adjacent to the mines and within the same river drainage basin, but was undisturbed by mining activities. The fragmented forest treatment included mature forest on midslopes and along first and second order streams that were almost entirely surrounded by reclaimed mine land. Grassland areas, estimated to be 5–19 yr of age, consisted primarily of grasses and scattered shrubs Shrub/pole areas were made up of shrub and pole-sized vegetation and ranged from 13–27 yr of age. Lack of succession on some older grassland sites resulted in an overlap in age for the latter two treatments. Wetlands were scattered throughout the grassland and shrub/pole treatments, the majority were "fill" ponds located at the bottom of reclaimed hillsides to collect sediment due to erosion. The fragmented forest treatment also contained fill ponds that were located at the bottom of reclaimed grassland hillsides adjoining the forest patch.

The intact and fragmented forest areas were comprised of mature Appalachian hardwood species typical of mixed mesophytic forest (Strausbaugh and Core

1977). Common species included red and white oak (*Quercus rubra* and *Q. alba*), pignut and shagbark hickory (*Carya glabra* and *C. ovata*), yellow poplar (*Liriodendron tulipifera*), and American beech (*Fagus grandifolia*). Primary vegetation on grassland areas was tall fescue (*Festuca arundinacea*), sericea (*Lespedeza cuneata*), and autumn olive (*Elaeagnus umbellata*); but also included multiflora rose (*Rosa multiflora*), legumes such as birdsfoot trefoil (*Lotus corniculatus*) and purple vetch (*Vicia americana*), and occasionally patches of planted wheat (*Triticum aestivum L.*). There were two distinct shrub/pole treatments. The first type consisted mostly of black locust (*Robinia pseudoacacia*), European black alder (*Alnus glutinosa*), and *Rubus* species. The second type included primarily coniferous species such as red pine (*Pinus resinosa*), Scotch pine (*P. sylvestris*), and pitch pine (*P. rigida*).

METHODS

We quantified Red-shouldered Hawk presence and relative abundance at 48 sampling points located in 14 stream drainages with 1–6 points within each drainage. Each of the 14 stream drainages were ≥1000 m apart. Within a drainage, points were spaced approximately 350–1320 m ($\bar{x}$ = 733 m) apart. Because there were no instances of a Red-shouldered Hawk being detected multiple times among the points <800 m apart, we believe that lack of independence between sample points did not influence our data. Sample points were divided equally among the four treatment types with 12 points in each treatment. Because one mine lacked the shrub/pole habitat, the number of sample points at each of the three mines (19, 18, and 12) varied slightly. All 48 points were sampled monthly (February 2000–January 2001) over a 4–6-d period with at least three treatments sampled on a given day to minimize temporal variability between treatments. A set of points representing at least three treatment types for each mine was assigned to be surveyed on a given day. The original order that those points were sampled was randomly established during the first survey. In subsequent surveys, the order in which points were sampled was systematically varied throughout the sampling day.

Broadcasting conspecific vocalizations has been shown to be an effective way to survey targeted raptor species (Rosenfield et al. 1988, Mosher et al. 1990, Kennedy and Stahlecker 1993). During winter months, we conducted broadcast surveys from one-half hr after sunrise until 1600 H because raptors can be active throughout the day during cooler weather. During summer months, we conducted surveys from one-half hr after sunrise until 1300 H, because shifts in raptor activity in the afternoon may reduce the detectability of certain raptor species such as Red-tailed Hawks and *Accipiters* (Bunn et al. 1995). Two observers trained in identification of raptors by sight and sound were present at every survey. During the survey period, both observers simultaneously watched and listened for raptors. Data recorded included latency (time from start of survey until first raptor detection), raptor species detected, age and sex (if possible), behavior during detection (perch and call, flyby and call, silent perch, silent flyby, vocal only), time each individual bird was seen, estimated distance bird was from observer, and treatment in which a bird was first detected. Surveys were not conducted in inclement weather (moderate to heavy rain, fog, or wind).

Broadcast surveys lasted 10 min and were based on the Fuller and Mosher (1987) protocol. We used a TOA Transistor® megaphone speaker[2] (Frederick Goertz Ltd., Victoria, BC) with an attached CD player for broadcasting calls. One observer held the speaker 1.5 m above the ground and rotated 120° between each broadcast. Broadcast call volume was adjusted between 100–110 db at 1 m from the speaker. Using the same broadcast volume, Mosher et al. (1990) estimated that calls could be heard ca. 0.75 km from the speaker. Before and after leaf-out, mean decibel readings at 50 m from the speaker were similar between the four treatments (Balcerzak 2001). Vocalizations alternated between Great-horned Owl (*Bubo virginianus*) and Red-shouldered Hawk calls during broadcasting. Both calls were recorded from the Peterson Field Guide to Bird Songs of Eastern and Central North America CD (Peterson Field Guide Series 1990). Mosher and Fuller (1996) found that Great-horned Owl vocalizations were able to elicit responses from a variety of raptor species on a single survey. McLeod and Andersen (1998) compared conspecific and Great-horned Owl calls in attracting Red-shouldered Hawks and found that Red-shouldered Hawks responded to Great-horned Owl vocalizations, although response rates were higher for conspecific vocalizations earlier in the season and in the day. Therefore, we used both calls within a survey period to maximize detection of a number of raptor species (Balcerzak 2001) as well as specifically target Red-shouldered Hawks. We randomly selected one call to start the first survey each day. We then alternated the starting call throughout the entire daily session.

For landscape-level habitat analysis, each survey point was geographically referenced using a global positioning system (GPS) receiver. Using a Geographic Information System (GIS), we determined landcover from U.S. Geological Survey (USGS) Digital Orthophoto Quadrangle (DOQ) images within 1000-m radius buffer zones placed around each broadcast station. The 1000-m radius (3.14 km^2, 314 ha) zone was based on the maximum home range size for Red-shouldered Hawks (Bednarz and Dinsmore 1981, Crocoll 1994). Although there was some overlap between the 1000-m buffer zones around broadcast points within a stream drainage, we completed landscape analyses for each individual point because we felt it would better reflect the habitat available to a bird detected at a given point. We classified landcover within the buffer zones into nine types: early-successional grassland habitat, mid-successional shrub/pole habitat (coniferous and deciduous), late-successional forest habitat (coniferous and deciduous), development, roads/bare ground, open water, and wetland. The ESRI® ArcView extension Patch Analyst 2.2 (ESRI, Redlands, CA) was used to analyze habitat composition of the 1000 m buffer zone and to calculate estimated values for 19 landscape variables (Table 1).

We summarized vegetation data collected at 156 points spaced ≥250 m apart within the 14 stream drainages into

[2] Use of tradenames does not imply endorsement by the Federal Government.

Table 1. Abbreviations and descriptions of 19 variables used in landscape analyses of habitat use of Red-shouldered Hawks in southern West Virginia during February 2000–January 2001.

ABBREVIATION	DESCRIPTION
DEVELOPMENT	Amount of human development (in ha). Includes residential and commercial buildings.
EARLY-SUCC. GRASS	Amount of early successional habitat (in ha). Consists of mostly grasslands and scattered shrubs.
LATE-SUCC. CONIFER	Amount of late successional habitat (in ha). Consists of mature, coniferous forest, mostly Eastern hemlock (*Tsuga canadensis*).
LATE-SUCC. DECIDUOUS	Amount of late successional habitat (in ha). Consists of mature, deciduous forest, mostly northern red oak (*Quercus rubra*), white oak (*Q. alba*), yellow poplar (*Liriodendron tulipifera*), and American beech (*Fagus grandifolia*).
MID-SUCC. CONIFER	Amount of mid-successional habitat (in ha). Consists of coniferous shrub/pole, mostly red pine (*Pinus resinosa*), Scotch pine (*P. sylvestris*), and pitch pine (*P. rigida*).
MID-SUCC. DECIDUOUS	Amount of mid-successional habitat (in ha). Consists of deciduous shrub/pole, mostly black locust (*Robinia pseudoacacia*), European black alder (*Alnus glutinosa*), and *Rubus* species.
ROAD	Amount of primary/secondary roads and bare ground (in ha). Includes all paved and most gravel/dirt roads and any area without vegetation.
WATER	Amount of open water (in ha). Includes all streams, rivers, lakes, and ponds.
WETLAND	Amount of emergent palustrine wetland (in ha).
FOREST	Amount of total mature forest (in ha). LATE-SUCC. CONIFER and LATE-SUCC. DECIDUOUS combined.
No. FOREST PATCHES	Number of total FOREST patches.
FOREST PATCH SIZE	Mean patch size of FOREST.
CORE AREA	Total core area of FOREST in the landscape (100-m buffer used).
CORE PATCH SIZE	Mean patch size of total core area of FOREST in the landscape.
EDGE DENSITY	Edge density. Measure of amount of edge relative to the landscape area.
DIVERSITY INDEX	Shannon's Diversity Index. Measure of relative patch diversity in the landscape.
EVENNESS INDEX	Shannon's Evenness Index. Measure of patch distribution and abundance in the landscape.
DISTANCE TO WATER	Distance to nearest WATER or WETLAND (in m).
DISTANCE TO TREATMENT	Distance to next habitat/treatment type (in m).

23 variables for use in microhabitat analyses (Table 2). Four vegetation subplots of 11.3-m radius (0.04 ha) were sampled per point with one subplot centered on the point and three subplots ca. 35 m away from the center spaced 120° apart (0°, 120°, and 240°). We recorded tree species and tree diameter at breast height (DBH) >8 cm within each 11.3-m-radius subplot. Within a 5-m radius centered on each subplot, we counted shrubs, saplings, and poles taller than 0.5 m and with DBH ≤8 cm. We measured six categories of ground cover and six categories of canopy cover using a "hit or miss" method with an ocular sighting tube at five points along four 11.3-m transects that radiated north, south, east, and west from the center of the vegetation subplot (James and Shugart 1970). Canopy cover height classes were visually estimated. For each subplot, canopy height and slope were measured with a clinometer, aspect was measured with a compass, and elevation was derived with a GPS receiver.

We used analysis of variance (ANOVA) to compare mean abundance of Red-shouldered Hawks among treatments. Mean abundance was calculated as the mean number of detections per point per month across all treatments. In the ANOVA model, mean abundance was the dependent variable, while treatment, season, and the interaction between treatment and season were independent variables. We defined three seasons: winter (December–March), summer (April–July), and migration (August–November). We also used ANOVA to compare microhabitat characteristics across treatments. The ANOVA models included the microhabitat variables as the dependent variable; independent variables were treatment, mine, and the interaction between treatment and mine. When differences between treatments were detected by ANOVA, we used the Waller-Duncan K-ratio *t* test to determine where those differences occurred.

We used Student's *t*-tests to compare mean values of landscape variables between points with and without Red-shouldered Hawk detections. We also used stepwise logistic regression to identify landscape characteristics important to presence of Red-shouldered Hawks. Similar to

Table 2. Abbreviations and descriptions of 23 microhabitat variables compared across treatments in southern West Virginia during February 2000–January 2001.

ABBREVIATION	DESCRIPTION
ASPECT	Aspect (degrees) taken at the center of plot.
SLOPE	Slope (degrees) taken at the center of plot.
ELEVATION	Elevation (m) taken at center of plot.
DISTANCE TO EDGE	Distance to nearest microhabitat edge (m). Includes roads, openings, and streams, or any other significant edge in forest microhabitat.
CANOPY HEIGHT	Average canopy height (m).
SNAG	Number of snags/dead trees.
Ground cover:	
BARE GROUND	Percent of ground area covered by no vegetation.
GREEN	Percent of ground area covered by vegetation.
WATER	Percent of ground area covered by water.
LITTER	Percent of ground area covered by leaf litter.
MOSS	Percent of ground area covered by moss.
WOODY DEBRIS	Percent of ground area covered by woody debris.
Tree class categories:	
SAPLING	Number of trees <2.5 cm DBH.
POLE	Number of trees ≥2.5–8 cm DBH.
MID-SIZED TREE	Number of trees >8–38 cm DBH.
LARGE TREE	Number of trees >38 DBH.
Canopy cover:	
CANOPY 0–3 m	Mean canopy cover for <0.5–3 m.
CANOPY 3–6 m	Mean canopy cover for >3–6 m.
CANOPY 6–12 m	Mean canopy cover for >6–12 m.
CANOPY 12–24 m	Mean canopy cover for >12–18 m.
CANOPY ≥24 m	Mean canopy cover for >24 m.
VERTICAL STRUCTURE	Sum of all canopy "hits" with ocular sighting tube (min = 0, max = 120).

Mitchell et al. (2001), we did not eliminate any variables *a priori* from the analyses because little is known about Red-shouldered Hawk habitat use in a reclaimed mine landscape. The Hosmer and Lemeshow (H/L) Goodness-of-fit test was used to determine the fit of the logistic regression model. The entry and stay levels (α levels) for the logistic regression models were set at 0.3 and 0.1, respectively. We initially developed logistic regression models using all 48 points in all four treatments to determine if broad-scale features enabled Red-shouldered Hawks to persist in a reclaimed mine landscape. We then developed models for just the two forest treatments to more specifically examine features of fragmented and intact forest.

All statistical analyses were completed using the SAS® GLM, LOGISTIC, and TTEST procedures (SAS® Institute 1991). We set the significance level for all statistical tests at $\alpha = 0.1$.

RESULTS

From February 2000–January 2001, we recorded 30 detections of Red-shouldered Hawks on broadcast surveys, with 19 of the 48 points having at least one detection. Of the four detections in shrub/pole, three were aural and one was visual. In fragmented forest, eight detections were aural, two were visual, and four were both. In intact forest, five detections were aural, two were visual, and four were both.

Mean abundance of Red-shouldered Hawks was significantly different among treatments ($F = 2.57$, df = 3, $P = 0.053$). The multiple comparison test indicated that mean abundance was significantly higher in the intact forest ($\bar{x} = 0.07$ detections/point, SE = 0.03) than the grassland ($\bar{x} = 0.01$, SE = 0.01) treatment but did not differ from the fragmented forest ($\bar{x} = 0.03$, SE = 0.01) or shrub/pole ($\bar{x} = 0.03$, SE = 0.01) treatments.

As expected, most microhabitat characteristics in both fragmented and intact forest differed from shrub/pole and grasslands (Table 3). Comparing fragmented and intact forest, the primary differences in microhabitat characteristics were greater

Table 3. Means and standard errors (SE) of microhabitat characteristics in grassland ($N = 44$), shrub/pole ($N = 33$), fragmented forest ($N = 36$), and intact forest ($N = 49$). Within a row, means with different letters differ at $P < 0.05$ (Waller-Duncan *k*-ratio test).

Variable	Grassland		Shrub/Pole		Fragment		Intact			
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*F*	*P*
ASPECT	1.05	0.10	0.77	0.11	1.05	0.12	1.03	0.08	1.86	0.1393
SLOPE (%)	16.96 B	2.10	10.16 C	1.93	33.78 A	2.28	33.75 A	2.07	42.95	<0.0001
ELEVATION (m)	400.27 A	7.47	378.85 B	11.53	332.08 C	7.11	399.47 A	11.24	24.94	<0.0001
DISTANCE TO EDGE (m)	113.02 A	16.75	68.14 B	8.23	38.71 B	3.88	64.61 B	11.57	4.69	0.0037
CANOPY HEIGHT (m)	—	—	4.68 B	0.46	21.77 A	0.73	22.98 A	0.67	222.63	<0.0001
SNAG (no./ha)	0.00 C	0.00	14.03 B	4.88	41.87 A	3.99	46.57 A	6.26	111.33	<0.0001
Ground Cover (%)										
BARE	7.73 B	1.18	2.22 B	0.92	7.71 A	0.95	7.45 A	0.59	13.19	<0.0001
GREEN	82.78 B	2.00	85.86 A	3.47	30.35 C	1.74	36.61 C	1.99	130.34	<0.0001
WATER	0.14 B	0.10	0.15 B	0.12	1.15 A	0.32	0.48 B	0.17	4.19	0.0070
LITTER	8.14 C	1.54	6.06 C	1.78	54.24 A	1.88	48.32 B	1.75	230.03	<0.0001
MOSS	1.04 B	0.38	1.83 B	0.86	2.01 A	0.32	2.04 A	0.34	5.48	0.0013
WOOD	0.06 B	0.04	0.30 B	0.12	4.20 A	0.42	4.95 A	0.41	140.93	<0.0001
Tree class categories (no./ha)										
SAPLING	777.70 B	207.52	7475.38 A	1646.08	4935.76 A	450.55	6135.84 A	702.59	67.03	<0.0001
POLE	73.15 C	18.79	979.17 B	292.52	901.04 A	65.86	587.37 AB	55.71	79.55	<0.0001
MID-SIZED TREE	0.03 C	0.02	132.58 B	23.72	429.17 A	35.26	352.93 A	12.90	565.54	<0.0001
LARGE TREE	0.00 B	0.00	0.00 B	0.00	44.27 A	3.77	42.35 A	3.17	993.28	<0.0001
Canopy cover (%)										
CANOPY 0–3 m	—	—	29.70 C	2.94	54.90 A	2.33	47.63 B	2.33	25.16	<0.0001
CANOPY 3–6 m	—	—	22.88 C	2.86	66.63 A	2.42	54.67 B	2.06	75.63	<0.0001
CANOPY 6–12 m	—	—	14.37 B	2.59	63.06 A	2.38	65.46 A	1.24	148.67	<0.0001
CANOPY 12–24 m	—	—	2.84 C	0.86	56.01 B	2.68	63.34 A	2.07	280.81	<0.0001
CANOPY 18–24 m	—	—	0.11 C	0.08	41.39 B	2.97	51.28 A	3.06	180.95	<0.0001
CANOPY ≥24 m	—	—	0.00 B	0.00	16.15 A	2.48	18.06 A	2.14	36.62	<0.0001
VERTICAL STRUCTURE	—	—	13.98 B	1.47	59.63 A	1.29	60.09 A	1.39	339.75	<0.0001

Table 4. Results of Student's *t*-tests showing mean and standard error (SE) of the 19 landscape variables within 1000-m buffer zones for presence/absence of Red-shouldered Hawks at 48 broadcast survey points in southern West Virginia during February 2000–January 2001.

	ALL TREATMENTS[a]				FOREST TREATMENTS[b]			
	PRESENCE		ABSENCE		PRESENCE		ABSENCE	
VARIABLE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
DEVELOPMENT	0.82	0.40	1.94	0.67	0.38	0.26	2.55	1.27
EARLY-SUCC. GRASS[c]	93.50	19.41	102.36	15.83	108.23	27.25	52.18	17.01
LATE-SUCC. CONIFER	19.41	4.06	16.52	3.40	23.65	5.40	17.86	4.64
LATE-SUCC. DECIDUOUS[c]	152.70	17.92	160.53	17.38	161.68	27.55	227.90	20.87
MID-SUCC. CONIFER[c]	3.24	2.21	2.02	1.26	0.00	0.00	0.06	0.03
MID-SUCC. DECIDUOUS	31.44	10.24	16.64	5.38	7.42	4.30	4.74	2.67
ROAD	9.10	1.51	10.47	2.10	8.68	2.27	5.99	1.99
WATER	1.79	0.45	1.54	0.25	1.70	0.44	1.01	0.37
WETLAND[c]	0.58	0.15	0.54	0.12	0.82	0.23	0.28	0.12
FOREST[c]	172.11	19.58	177.05	17.75	185.34	29.42	245.76	19.71
No. FOREST PATCHES	5.84	0.89	5.69	0.84	5.73	1.17	5.77	1.55
FOREST PATCH SIZE	61.95	20.65	80.87	20.34	83.73	34.47	140.06	39.09
CORE AREA	91.50	20.10	103.93	18.59	111.27	32.71	170.53	29.43
CORE PATCH SIZE	61.59	20.04	75.58	19.23	88.53	32.46	136.82	35.33
EDGE DENSITY	220.51	13.77	213.00	15.08	212.13	20.61	187.86	30.65
DIVERSITY INDEX	2.99	0.11	2.82	0.13	2.93	0.16	2.51	0.24
EVENNESS INDEX	0.73	0.02	0.72	0.01	0.70	0.02	0.70	0.02
DISTANCE TO WATER	378.02	102.78	407.75	76.97	437.37	173.82	600.85	149.12
DISTANCE TO TREATMENT	434.79	183.13	581.51	161.14	612.05	298.01	1034.15	318.51

[a] Includes all four treatments: grassland, shrub/pole, fragmented forest, and intact forest, $N = 48$.
[b] Includes fragmented forest and intact forest treatments only, $N = 24$.
[c] Indicates significant difference between means for the forest treatment at $\alpha = 0.1$.

amounts of water, litter, and low canopy (CANOPY 0–3 m, CANOPY 3–6 m) cover in fragmented forest. Intact forest generally had greater amounts of the higher canopy covers (CANOPY 12–18 m, CANOPY 18–24 m), although supercanopy cover (CANOPY 24 m) was similar between intact and fragmented forest.

At the landscape level, no variables were retained as predictors of Red-shouldered Hawk presence when all treatments were included in the logistic regression analyses. For the fragmented and intact forest points, the amount of wetland (WETLAND) in the landscape was the only predictor of presence (H/L Goodness-of-fit = 0.498, χ^2 = 3.580, $P = 0.059$). Additionally, wetlands occurred at 14 of the 19 points where Red-shouldered Hawks occurred, and wetland habitat was more abundant ($t = -2.21$, df = 22, $P = 0.038$) at forested points with Red-shouldered Hawk presence (Table 4). Student's *t*-tests indicated that early-successional reclaimed grassland habitat (EARLY-SUCC. GRASS) was more abundant, while late-successional forest (LATE-SUCC. DECIDUOUS), mid-successional coniferous forest (MID-SUCC. CONIFER), and total mature forest (FOREST) were less abundant at forested points where Red-shouldered Hawks were present (Table 4).

DISCUSSION

Red-shouldered Hawks had significantly higher abundance in the intact forest treatment than the grassland treatment, but not compared to the fragmented forest or shrub/pole treatments. Observations of birds outside the treatment at the survey point were dropped from analyses, therefore, 18 of 23 detections (nine intact forest, four fragmented forest, four shrub/pole, one grassland) were used in statistical comparisons among treatments. When all 23 detections of Red-shouldered Hawks were classified into the habitat treatment where the bird occurred: 10 were in intact forest, eight in fragmented forest, four in shrub/pole, and one in grasslands. Many studies have shown these birds to nest primarily in contiguous, mature forest habitat

(Bednarz and Dinsmore 1981, Morris and Lemon 1983, Belleman 1998). During the study, only one Red-shouldered Hawk responded to broadcast surveys in fragmented forest during the breeding season (Balcerzak 2001). Overall, more Red-shouldered Hawks responded in intact forest during the breeding season (four detections), including one instance where two birds were observed together during a survey and may have been a nesting pair. Additionally, two–three Red-shouldered Hawks (possibly juveniles) were observed at an intact forest site in August, so breeding may have occurred in the area. Thus, it is possible that Red-shouldered Hawks may be using fragmented patches of forest for hunting or roosting, but using intact forest for nesting. Although analyses of microhabitat characteristics suggested few major differences between fragmented and intact forests, the amount of water as ground cover was greater in fragmented forests which may provide better foraging opportunities. Red-shouldered Hawks were detected in the shrub/pole and grassland treatment only during migration and winter periods (Balcerzak 2001). Some studies have reported greater use of more open areas and woodland edges by Red-shouldered Hawks during the winter months as compared to summer months (Bohall and Collopy 1984, Crocoll 1994).

The only significant predictor of Red-shouldered Hawk presence at the landscape level was the amount of WETLAND within the 1000-m buffer zone for points within the two forest treatments. WETLAND was not significant for the overall logistic regression models that included all 48 points and all treatments. Many of the ponds and wetlands in the study area occurred within the early-successional grassland found on the reclaimed mine sites. Throughout the year of surveys, only one juvenile Red-shouldered Hawk was detected flying over the open grassland of the mine, so any significance WETLAND may have had on Red-shouldered Hawk presence for the overall landscape regression models was mitigated by the low occurrence of Red-shouldered Hawks in the grasslands. The significance of the variable WETLAND for points within fragmented and intact forest, where a majority of Red-shouldered Hawk observations occurred, suggests that Red-shouldered Hawks are frequenting landscapes that contain a higher amount of wetlands, but that also are associated with mature forest. Amount of open water (WATER) and DISTANCE TO WATER/wetland were not significant in any of the landscape regression models, suggesting that these two variables were not as important as the amount of palustrine emergent wetland habitat present in the landscape.

Wetlands have been associated with macrohabitat of Red-shouldered Hawks in a number of studies. Both Bednarz and Dinsmore (1981) and Bosakowski et al. (1992) found wetlands to be significant in the landscape surrounding Red-shouldered Hawk nests, while Howell and Chapman (1997) determined that a majority of Red-shouldered Hawk home ranges were within bottomland forest containing perennial streams, seasonal pools, and beaver ponds. Dykstra et al. (2001) found Red-shouldered Hawk response to broadcast surveys correlated with the number of small ponds within stream corridors. Red-shouldered Hawk association with wetlands may be related to diversity and abundance of amphibian prey. A majority of prey items delivered to Red-shouldered Hawk nests were prey associated with aquatic or moist habitats (Bednarz and Dinsmore 1981, Howell and Chapman 1997). Snakes, toads, lizards, and frogs are common prey for Red-shouldered Hawks in the eastern U.S. (Peterson and Crocoll 1992, Crocoll 1994). Many of the ponds and wetlands associated with the reclaimed grassland and fragmented forest in our study did contain populations of frogs, in particular bullfrogs (*Rana catesbeiana*).

Although most variables associated with the reclaimed mine present on the study sites (EARLY-SUCC. GRASS, MID-SUCC. DECIDUOUS DISTANCE TO TREATMENT) were not significant at a landscape scale in regression analyses, there was significantly more EARLY-SUCC. GRASS, and significantly less MID-SUCC. CONIFER, LATE-SUCC. DECIDUOUS, and FOREST at forest sites in the 1000-m buffer zone where Red-shouldered Hawks were present. This suggests that Red-shouldered Hawks can tolerate a measure of fragmentation (forest edge) within the landscape, which some studies have indicated may be important for foraging (Bednarz and Dinsmore 1982, Moorman and Chapman 1996). Although forested points where Red-shouldered Hawks were present contained more grassland and less forest overall, generally, multiple detections of Red-shouldered Hawks occurred at more intact forest points and few Red-shouldered Hawks were ever observed within reclaimed mine habitat, and then only during the non-breeding season (Balcerzak 2001). The reclaimed portions of the three mines in our study were 1800–2500 ha in size, so such a large expanse of open land with little to no cover may have deterred Red-shouldered Hawks from using this habitat, regardless of the high amount of wetlands present. Generally, the grasslands had very few perches, especially adjacent to wetlands, which could explain low use of this area by hunting Red-shouldered Hawks. Bloom et al. (1993) found that Red-shouldered Hawks in California only used non-wooded areas when perches were present. Although wetlands were a significant factor determining Red-shouldered Hawk presence, this was only in combination with some mature forest present, indicating that the large size of the grasslands and lack of perches are likely the main reasons Red-shouldered Hawks were rarely observed using this habitat and associated wetlands.

In summary, our study, similar to others, found that the amount of wetland within a landscape containing mature forest is an important habitat characteristic determining presence of Red-shouldered Hawks. Many of the wetlands found along drainages of forested valleys within the landscape originated with fill ponds created to control soil erosion from reclaimed mine sites. Thus, it may be that Red-shouldered Hawks have taken advantage of the increased amount of wetlands created by past mining activities, but also need an undetermined amount of mature forest present. Interestingly, amount of grasslands and various measures of forest fragmentation were not important in predicting presence, even though Red-shouldered Hawks were rarely observed in grassland and shrub/pole habitat (Balcerzak 2001). Differences in seasonal use and limited sample size may have influenced this lack of pattern. The large size of the grasslands and lack of available perches for hunting likely contributed to low Red-shouldered Hawk use of reclaimed areas. More wetlands in the landscape may provide for a large population of amphibians and reptiles, important in the diet of Red-shouldered Hawks. Use of reclaimed lands by Red-shouldered Hawks might be enhanced and accelerated by planting hardwood trees near ponds and wetlands.

ACKNOWLEDGMENTS

This research was conducted as part of an Environmental Impact Assessment examining the effects of mountaintop mining on terrestrial vertebrates. Funding was provided by the West Virginia State Legislature and the Environmental Protection Agency. We also thank Arch Coal, Cannelton, and Amherst Corporation for allowing access to their properties. Ark Land Company provided field housing. The West Virginia Cooperative Fish and Wildlife Research Unit, BRD/USGS at West Virginia University provided logistical support and field equipment. Special thanks go to the many people who helped with surveys, in particular Dorothy Tinkler and John D. Anderson, and to Mike Strager for providing help and guidance with GIS analysis. Thanks also to Roger J. Anderson, Cheryl Dykstra, John W. Edwards, and two anonymous reviewers for helpful comments on this manuscript. This is West Virginia Agricultural and Forestry Experiment Station scientific article no. 2847.

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Received 29 May 2002; accepted 21 May 2003